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PRELIMINARY EVALUATION OF THE MULTIPURPOSE ARCADE COMBAT SIMULATOR (MACS) FOR THE M16, M203, AND M72A2

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Limited experimental evaluations were performed on the Multipurpose Arcade Combat Simulator (MACS) configured for the M16 Rifle, M203 Grenade Launcher, and M72A2 Light Antitank Weapon. Computer training programs were written for each configuration and field tested using soldiers undergoing One Station Unit Training (OSUT). The results indicate that MACS training, when given prior to live fire instruction, may give soldiers a head start on acquiring marksmanship skills. In the studies in which MACS training was limited to a brief exposure prior to live-fire training, there was a trend for

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PRELIMINARY EVALUATION OF THE MULTIPURPOSE ARCADE COMBAT SIMULATOR (MACS) FOR THE M16, M203, AND M72A2

EXECUTIVE SUMMARY

Requirement:

The purpose of this investigation was to conduct limited experimental evaluations of the current Multipurpose Arcade Combat Simulator (MACS) software compared to standard training. This part-task simulator is composed of an inexpensive microcomputer, light pen attached to a weapon, and a color video monitor. Configurations were developed for three U.S. Army Infantry weapons that were identified in a previous study as likely candidates for MACS. These weapons are: M16 Rifle, M203 Grenade Launcher, and the M72A2 Light Antitank Weapon.

Procedure:

Computer training programs, tailored to the One Station Unit Training (OSUT) program of instruction, were written for each of the three MACS configurations: MACS M16, MACS M203, and MACS M72A2. Separate evaluations, using different OSUT companies, were conducted for each weapon. The primary dependent variable was the live-fire performance of the experimental group (soldiers who received MACS training in addition to regularly scheduled training) compared to the control group (regularly scheduled training only). Additionally, an opinion questionnaire was administered to the experimental group to assess subjective usefulness of MACS.

Findings:

The data indicated that MACS training, when given prior to live-fire instruction, may give soldiers a head start in the acquisition of marksmanship skills. In the MACS M203 and MACS M72A2 studies, which limited MACS training to a brief exposure prior to live-fire training, there was a trend for the experimental groups to hit more targets and to place live rounds closer to the center of mass of the target, especially on the farther targets. MACS was found to have a statistically significant live-fire transfer effect for the M203 grenade launcher. The MACS M16 experimental group spent over 500% more time on the simulator than did the trainees in the MACS M203 or MACS M72A2 studies, and the exposure was distributed concurrently with regularly scheduled training. However, although statistically significant within-MACS M16 improvements were found, comparisons with control subjects in live-fire tasks were not statistically significant.

The favorable responses on the opinion questionnaires support the potential usefulness of MACS as a training aid. The soldiers reported that MACS training was very interesting and helpful, and preferable to traditional concurrent training.

Utilization of Findings:

The results of this investigation indicated that MACS has potential as a cost-effective training aid and could contribute to a more favorable learning environment by providing (1) standardized instruction, (2) one-on-one instruction, and (3) a motivating head start to live-fire training. The experimental evaluations performed on the MACS M16, MACS M203, and MACS M72A2 configurations should be considered preliminary field tests which should be followed by further development. Since the results indicated that the effectiveness of MACS may vary as a function of exposure schedule, further investigation is recommended to determine the most appropriate stage of training to use MACS, and the amount of time needed to impart an effect.

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INTRODUCTION

Simulators are a viable response to efforts to contain training expenses yet maintain high standards of instruction. Every soldier in the Army must complete initial entry training, during which the Army will spend a minimum of $1,185 per soldier on ammunition alone (Perkins & Schroeder, 1983). Although this financial outlay is substantial, it is not enough. For example, some soldiers need additional firing practice to pass the Basic Rifle Marksmanship test. Furthermore, budget cuts have reduced M203 Grenade Launcher training from a 15-round qualification program to a 5-round familiarization program. Simulators can help bridge the training gap between what is financially practical and what is necessary to produce combat-ready soldiers.

Simulators also can make substantial contributions to high quality standardized instruction. The lower the student-to-instructor ratio, the more favorable the conditions are for learning, and simulators are a cost-effective way to optimize this ratio. Furthermore, simulators provide standardized instruction that ensures all trainees receive the same high quality training. Finally, motivation is an important factor for learning and simulators can stimulate interest in dry-fire exercises.

More than any factor, the microprocessor is responsible for the proliferation of simulators. The core element of most simulators is a computer of some sort, and the small size and low cost of the microprocessor has made many simulators feasible that would have been prohibitively large and expensive if run by a minicomputer. For example, in 1973 a minicomputer, plus peripherals, for one simulator cost $30,000 and was the size of a small refrigerator. In contrast, by 1980 the device had been redesigned around a microprocessor that cost about $3,000 (including peripherals) and was the size of a typewriter (McGlasson, 1983).

There is a commitment in the US Army to low-cost simulators oriented toward part-task training (Ludvigsen, 1981). However, a recent literature search for weapon simulators indicated that there are several very expensive simulators (e.g., the stationary target Weaponeer for $35,000, or the Unit Conduct of Fire Trainer for about $1.5 million), but nothing in a lower price range, around $2,000 to $4,000 (Perkins & Schroeder, 1983).

The Army Research Institute (ARI) Fort Benning Field Unit has developed an inexpensive part-task simulator (Schroeder, 1982). This development was partly in response to military training requirements that effective Infantry weapons simulators be developed inexpensively enough to be fielded in sufficient quantities to meet wide-spread needs. Factors contributing to the development of simulators of this type include the expense of ammunition for weapons training, high cost of competing simulator devices, and technological advances which make low-cost training aids financially practical. As illustrated in Figure 1, this simulator, called MACS (Multipurpose Arcade Combat Simulator) is composed of an inexpensive microcomputer, a light pen attached to a demilitarized weapon, and a color video monitor (Schroeder, 1982). The *simulator is multipurpose in that different weapons can be* "plugged into" the system by removing the light pen sensing device from one weapon and attaching it to another, and inserting a software disk into the computer's drive so that a training scenario appropriate for that weapon appears on the monitor.

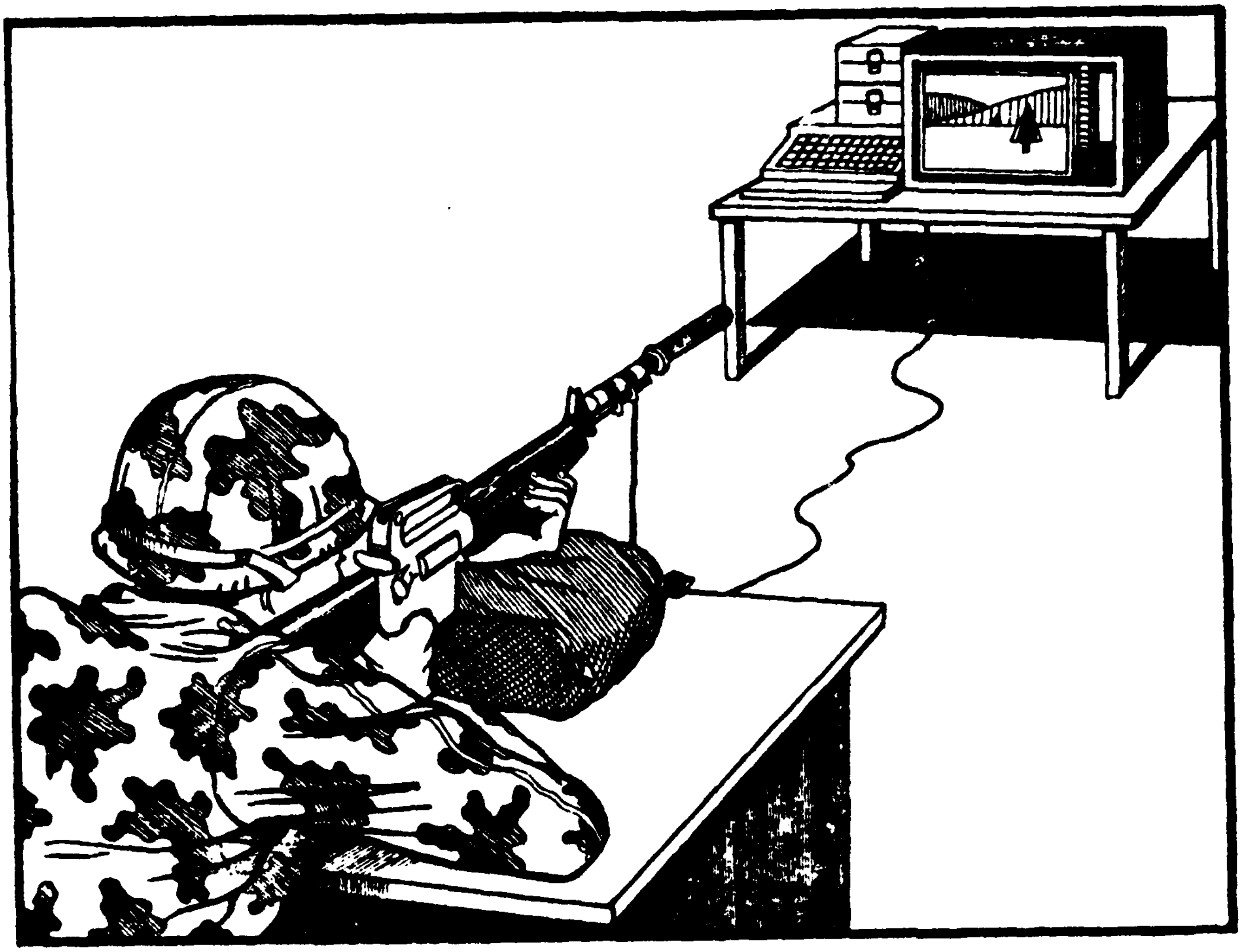

Figure 1. Illustration of the MACS M16 configuration.

An earlier study established which US Army Infantry weapons are most suitable for MACS, and the order in which these weapons should be addressed (Perkins & Schroeder, 1983). The following weapons, listed in order of suitability, were identified: (1) M16A1/A2 5.56mm Rifle, (2) M72A2 Light Antitank Weapon (LAW), (3) M203 Grenade Launcher, (4) M60 Machinegun, (5) Dragon, (6) TOW, (7) .45 Caliber Pistol, (8) M249 Squad Automatic Weapon (SAW), (9) M202A1 FLASH, and (10) .50 Caliber Machinegun. Instructional designs and computer software then were modified from the original ARI prototypes for the first three weapons, M16, M72A2, and M203.

Marksmanship training for the M16 receives considerably more time than the M203 or M72A2; therefore, program development was more extensive for the M16. The training guides available for the M16 (Basic Training POI 21-114; BRM Shooter's Book, and Unit Rifle Marksmanship Training Guide) describe the basic skills necessary for marksmanship: steady position, aiming, breath control, and trigger squeeze, and these formed the instructional objectives for the M16 software. All initial entry soldiers receive 48 hours of Basic Rifle Marksmanship (BRM) training prior to taking an M16 marksmanship qualification test, and this program provided the guidelines for the training scenarios simulated by MACS. Similarly, the tasks stated in the OSUT Program of Instruction (POI) for the M203 and the M72A2 (8 hrs training each) were simulated for the MACS M203 and MACS M72A2 scenarios.

This report details the results of preliminary evaluations performed on prototype MACS configurations for the M16, M203, and M72A2. These evaluations represent initial efforts to test equipment and courseware which are still in the developmental stage. The results of these investigations will provide guidelines for modifications, which will again be subjected to further testing. The presentation of the findings is organized into three sections, one for each configuration: MACS M16, MACS M203, and MACS M72A2. The major goal of this effort was to conduct a preliminary evaluation of the current MACS software and to provide recommendations for future directions for MACS development.

EVALUATION 1: MACS M16

The pilot evaluation of the MACS M16 programs began with introducing the soldiers to the M16 and ended with a qualification test of M16 marksmanship. Live-fire performance data generated during regularly scheduled BRM exercises were collected and comparisons were made between soldiers who did and did not receive supplemental MACS M16 training. It should be noted that the field data are possibly contaminated by a number of sources of error which were beyond the experimenters' control. Nevertheless, the data generated provide preliminary input about which MACS programs train the best, where potential hardware/software problems lie, where MACS should be implemented, and where changes, additions, or deletions in the software should be made.

Method

Subjects. The experimental and control groups were drawn from a company of Army trainees beginning Basic Rifle Marksmanship (BRM) training at Fort Benning, GA. All subjects were male. This company volunteered to participate in the MACS M16 study. Moreover, this company was composed of two regular Army platoons, and two platoons of National Guardsmen and Reservists, many of whom could not claim English as their first language. In the interest of sample homogeneity, a decision was made to draw subjects only from the two regular Army platoons. Because the platoon members had to stay together, a sample from one platoon became the experimental group and a sample from the other platoon became the control group. A flip of the coin decided which group would be the experimental group. Twenty-six soldiers were used from the experimental platoon and 30 soldiers from the control platoon. Inclusion of soldiers in the study was based on roster number: soldiers with the first 26 roster numbers in the experimental platoon formed the original experimental group, and the first 30 roster numbers formed the control group. However, during the investigation, two subjects were unavailable and the company commander replaced them with two soldiers who were not in roster sequence (i.e., roster #34 and #42.) It was assumed that assignment of roster number to each soldier was unbiased and inquiries into this process failed to identify any biases. Group size was based upon the maximum number of soldiers that could receive MACS training under the existing time and equipment constraints, with 6 and 10 additional subjects in the experimental and control groups, respectively, to control for attrition.

Apparatus. The hardware configuration of MACS is described in Schroeder (1982). For the M16, existing ARI programs were modified and new programs were written resulting in six programs, each compatible with the training objectives in the different stages of BRM instruction. A description of the MACS M16 programs is provided in Appendix A. The scale of the targets presented in MACS was verified by comparing the measurements taken from the screen to the values calculated mathematically, and by comparing photographic images of the targets as they appear on the monitor screen to photographs of targets at actual distances on a firing range. The target scale verification procedure is presented in more detail in Appendix B.

Procedure. Prior to the field evaluation, two pilot tests were conducted in which two sets of five troops beginning BRM training were brought into the ARI field station to try out the MACS M16 programs. At this time, any detected problems with the equipment or software were corrected. For the field evaluation, four MACS units were set up in a range shack near the BRM training sites. For each BRM period, the experimental group performed the live-fire exercises scheduled for that period of BRM with the rest of the company. The experimental group then was separated from the company and transported to the MACS range shack to receive training on the MACS program compatible with the BRM training just completed. BRM training also includes concurrent training which is held simultaneously with the live-fire exercises. During each BRM period, the platoons rotate through the live-fire and concurrent training stations. For the experimental group, concurrent training was conducted at the MACS evaluation site by an instructor provided by the Infantry Training Group. MACS was not intended to substitute for any training, rather it was intended to provide additional instruction. It should be noted that the experimental group received the concurrent training in a different training site than the rest of the company and, therefore, did not have access to any of the training aids (diagrams, posters, etc.) normally available.

The week long evaluation schedule is summarized in Figure 2. On the first day of MACS training, following BRM Period 2, the experimental group received AID (Aiming Instructional Device), and MACS Steady Position and Aiming Pretest, Training, and Posttest programs. However, there was not enough time to run everyone in the experimental group before they had to return to their mess area for lunch. Also, it was discovered that one of the light pens was not functioning properly, so the soldiers who had used the weapon with this pen needed to be retested. Consequently, 15 soldiers were exposed to MACS in the morning only (after BRM Period 2, but before any live firing in Period 3), 7 soldiers were tested that afternoon after Period 3, and 4 soldiers were run in both the morning and afternoon. After completing BRM Period 4, the experimental group received AID, MACS Steady Position and Aiming Training and Posttest, and worked through the MACS Down Range Feedback (DRF) program two times (DRF-1 and DRF-2). There was no time for MACS following Period 5. Following Period 6, the troops trained on three more iterations of MACS DRF (DRF-3, 4, and 5). MACS Field Fire I was presented twice following Period 7 (FFI-1 and FFI-2). Following Period 8, soldiers were given two presentations of the MACS Field Fire II Program. On the last day before qualification, the experimental group trained on MACS Record Fire after Period 9 (RF-1) and then again following Period 10 (RF-2). Each soldier spent at least 96 min. on MACS, and fired a minimum of 380 rounds over the 5-day period. There was no MACS training on the day of Record Fire qualification. After training on each of the MACS programs, members of the experimental group completed an opinion questionnaire. Copies of the questionnaire, with median responses, are presented in the results section. To determine the extent of shooting experience prior to entering the Army, a questionnaire was administered to all subjects prior to BRM or MACS training. A copy of this questionnaire is provided in Appendix C.

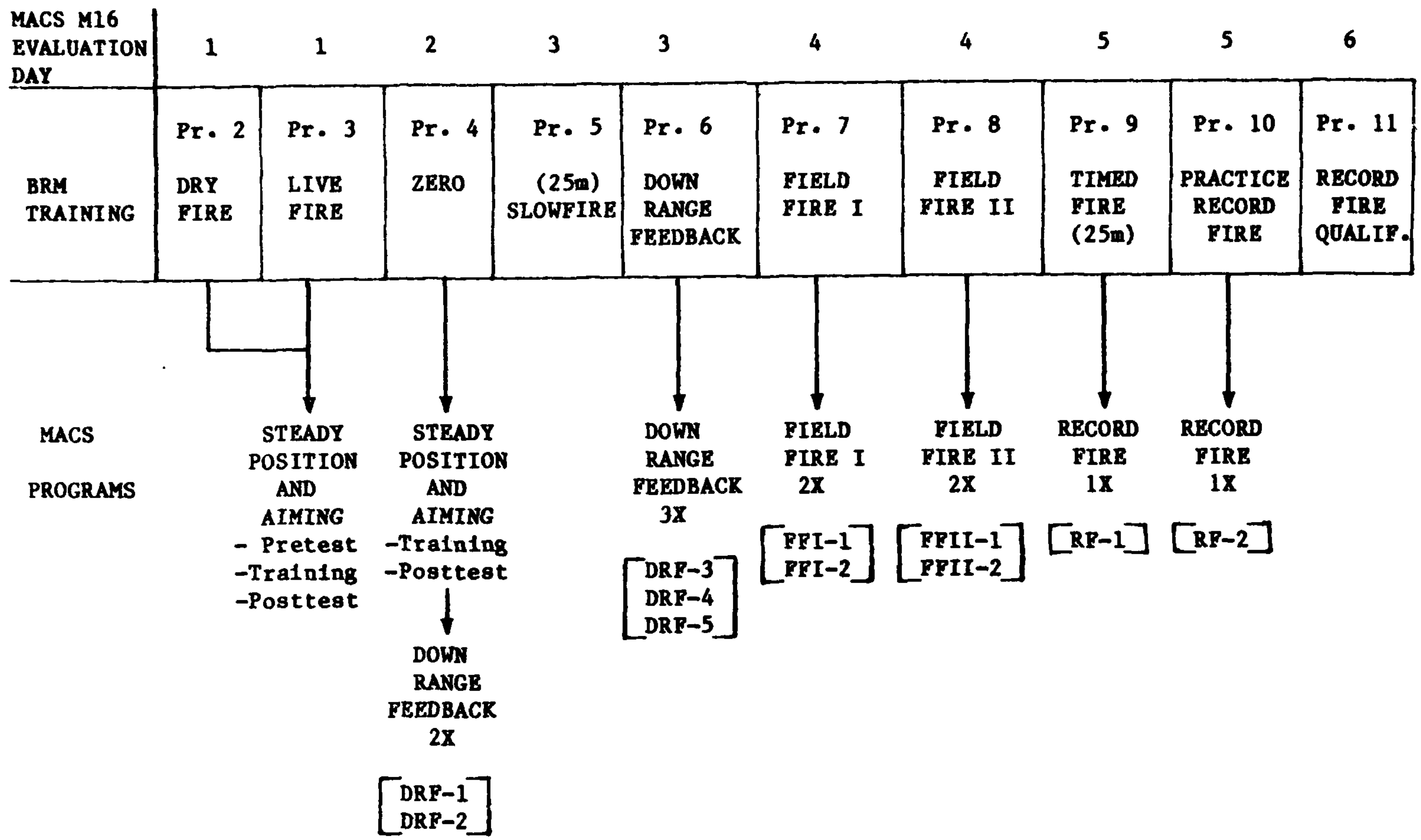

Figure 2. MACS M16 evaluation schedule.

During each period of BRM training, the live-fire performance of both the experimental and control groups was recorded. The following is a short description of each period of BRM instruction and the dependent measures (field data) collected for each period. However, the program was currently in revision at the time of this test. Unless otherwise specified, the performance of the experimental group was compared to that of the control group using t-tests.

Periods 1 and 2 - No data were collected.

Period 3 - Fundamentals of Shooting (Live Fire). The soldier learns how to shoot tight shot groups and to zero a rifle. Period 3 also introduces concurrent training in which an instructor presents new subjects or reviews previously presented material. Whenever the soldier is not on the firing line, he attends one or more concurrent training stations. The dependent variable was the number of rounds, out of 9 maximum, that hit a 25 m zero target. After the soldiers fired, the targets were collected and bullet holes were counted. This measure is confounded by not knowing why targets were missed. Absence of hits on targets can be classified broadly as either due to poor marksmanship, or due to factors unrelated to marksmanship, such as the weapon not being zeroed, a magazine containing fewer than 9 rounds, unzeroed weapon, weapon or ammunition malfunctions, or firing at the wrong target. These factors may have contributed to measurement error, but for statistical reasons it must be assumed that error was randomly distributed among both the experimental and control groups.

Period 4 - Practice Firing (Zero). During Period 4, each soldier fires as many 3-round shot groups needed to zero his rifle. An introductory lecture about the effects of wind and gravity on the flight of the bullet also is given. The dependent variable was the number of rounds (no maximum) needed to place a 3-round shot group within the 4 cm circle of a zero target presented at a range of 25 m. This can be a long exercise which does not end until all soldiers have zeroed or at dusk, whichever comes first. There was not enough time to close the range after each soldier zeroed to collect targets, therefore, data for this period were taken from the company's records which were generated by student coaches spotting for the firers. It is not known whether some soldiers needed more rounds to zero because of weapon malfunctions, confusion about how to adjust sights, difference in quality of original zero, inability to fire a tight shot group, etc.

Period 5 - Practice Firing (25 Meter Silhouette). Targets are scaled silhouettes representing 75, 175, and 300 m. Soldiers fire six rounds at each range in 3-round bouts for a total of 18 rounds. Firers and instructors walk down range to evaluate shot location after the first 9 rounds (fired from a foxhole supported position) and again after the last 9 rounds (fired from a prone unsupported position). The dependent variable was the number of rounds, out of 18, that hit six silhouettes scaled to represent 75, 175, and 300 targets, presented at a range of 25 m. Each soldier records hits and misses for each target on score cards provided by the instructors. An attempt was made to collect each soldier's targets, but the rain that day made this impossible. It is doubtful that the rain biased potential group differences since weather conditions were similar for both groups. The experimenters relied on soldiers reports.

Period 6 - Down Range Feedback, 75 and 175 Meters. During this period, soldiers engage targets at 75 and 175 m and then walk down range to see the results. These targets are actual size and at actual distances. They are placed on background paper so the soldier can see the location of most misses. Soldiers fire 30 rounds: 5 rounds supported position at the 75 m target, 5 rounds unsupported position at the 75 m target, and 10 rounds from each position at the 175 m target. Target presentations are timed at 5 sec for the 75 m target and 10 sec for the longer ranges. Evaluation of shot location occurs after 15 and 30 rounds. The dependent variable was the number of rounds, out of 30, that hit six silhouettes scaled to 75, 175, and 300 m. Each soldier records hits and misses for each target on score cards provided by the instructors. Additionally, Litton/ARI personnel provided the experimental and control groups with copies of the Basic Rifle Marksmanship Shooter's Book (Heller, Thompson, and Osborne, 1981), which contains miniature scaled targets, to record location of each round fired. Unfortunately, since there were insufficient Litton/ARI personnel to supervise accurate recording of shot location, and the cadre changed their instructions between the experimental and control groups, these data were very incomplete. However, the 10 rounds fired at the 75 m target were salvaged for both groups. In addition, the soldiers' reports about hits and misses were used in the analysis.

Period 7 - Field Fire (Single Targets) and Target Detection. Period 7 is conducted on a field fire range with two sizes of pop-up targets that fall when hit. The first size is the "E"-type representing a kneeling enemy soldier, and the second is the "F"-type representing an enemy soldier in the prone position. Only one target (75, 175, or 300 m) comes up at a time. The soldier has 5 sec to find, aim, and shoot the 75 and 175 m targets, and 10 sec for the 300 m target. An introduction to target detection also is included in Period 7. The dependent variable was the number of hits, out of 42 possible, on targets at ranges of 75, 175, and 300 m. Each firer has a student coach who records the firer's performance on a scorecard provided by the instructors. Data for this measure were taken from these records. Scoring of pop-up targets is subject to error such as failure by the scorer to detect a target, failure to recognize a target hit due to a target malfunction in which the target does not go down when hit, or assigning a hit when in fact the target was missed.

Period 8 - Field Fire (Single and Multiple Targets). Period 8 is similar to Period 7 except that more than one target may be exposed at a time. The 75, 175, and 300 m targets are again used for this instruction. The soldier has a time limit of 3 to 12 sec depending upon which target or combination of targets appear. The dependent variable was number of hits, out of a possible 36, on targets presented one or two at a time, for 5 to 12 sec, at ranges of 75, 175, and 300 m. Data collection and error sources were the same as for Period 7.

Period 9 - Zero and Timed Fire. Period 9 contains two different exercises. First, the rifle's zero is reconfirmed and improved if necessary. The second exercise is firing at a target containing several scaled silhouettes similar to those in Period 5, but with six ranges represented (50, 100, 150, 200, 250, and 300 m) and a limited time to fire at all the silhouettes (45 sec in the foxhole position and 55 seconds in the prone position). The dependent variable was the number of hits, out of 20 rounds, on 10 silhouettes scaled for 50, 100, 150, 200, 250, and 300 m. Litton/ARI personnel collected the targets and counted hits and misses for each range and firing position. Although Litton/ARI personnel were on the range to observe this exercise, there were not enough observers to carefully monitor all firing stations.

Period 10 - Practice Record Fire. This practice for record fire helps the soldier to see how well he is shooting and to learn about the qualification test to improve his score. The dependent measure was the number of targets hit, out of a possible 40, at ranges of 50 to 300 m, exposed one or two at a time, for 3 to 12 sec. Student coaches recorded the firer's number of hits on a scorecard. Possible sources of error are the same as those described for pop-up targets in Period 7. Again, there were insufficient Litton/ARI personnel to monitor every firing station.

Period 11 - Combat Firing and Record Fire. Period 11 is broken into two stages. In the first stage (Combat Firing), the soldier fires at 20 targets from the foxhole supported firing position, and 20 targets from the prone unsupported firing position. Firers are required to change magazines in the middle of firing and also are allowed to fire more than one round at missed targets. Combat Firing is so named because it is designed to simulate combat.

The second portion of Period 11 is Record Fire qualification. There are 40 timed targets (20 from the foxhole supported firing position and 20 targets from the prone unsupported firing position) with single and multiple exposures. Scoring for record fire is:

36-40 hits:	Expert
30-35 hits:	Sharpshooter
23-29 hits:	Marksman
22 or less:	Unqualified

Three firing lanes were designated for the experimental group, and three lanes for the control subjects. A Litton/ARI staff member was assigned to each lane and provided back-up scoring of hit/miss information to the range personnel. At the end of the day, the pop-up silhouette targets from these six lanes were collected, and the bullet holes in each target were counted to provide another measure of scoring reliability.

Results and Discussion

MACS M16 training did not improve BRM performance as measured by the number of hits in each of the BRM periods. Figure 3 illustrates that mean scores for each period of BRM were similar for soldiers who received MACS training compared to the control group. All t-tests were statistically nonsignificant.

It is possible that the groups were not matched on marksmanship ability prior to training, but a reliable measure of this was not available. Figure 4 illustrates that the two groups, in general, had a similar amount of shooting experience prior to BRM training. The most notable differences were in the amount of minimum experience and at the opposite extreme. Compared to the control group, there were 16% more soldiers in the experimental group with minimum experience (fired 1 to 50 rounds) but 8% fewer soldiers who reported to have fired over 1000 rounds. However, neither a χ^2 test using a median split nor a t-test of log number of rounds fired revealed significant differences in the two groups. Another indication of baseline marksmanship ability is performance in Period 3. Although there was a tendency for the control group to place more rounds on target, there was no significant difference in mean number of rounds on target (Figure 5). Performance during BRM Period 3 was a better predictor of later Record Fire scores than was previous experience. For the control group, there was a statistically significant correlation between Period 3 performance and Record Fire score ($r = .43$, $p < .05$).

It was intended that the experimental group receive the first program of MACS instruction prior to any live firing. However, due to time constraints, seven soldiers did not receive MACS training until after BRM Period 3 live-fire training. Nevertheless, soldiers in the experimental group who received MACS training prior to Period 3 had a similar number of rounds on target ($\bar{x} = 7.4$) compared to the soldiers in the experimental group who did not receive MACS training until after Period 3 ($\bar{x} = 7.5$).

During MACS exposure, a number of within-subject comparisons were made to determine within-MACS training effects for the experimental group. One such test assessed MACS's ability to train steady position. On the first MACS day, experimental subjects were given a test (pretest) during which six targets were presented. For each target presentation, numerous readings were taken by the MACS program prior to and during trigger manipulation in order to assess the subjects' ability to maintain a steady position. Next, the MACS Steady Position and Aiming program was presented. The instructional objective of this program is to train steadiness during trigger manipulation. Following this training program, the same test (now a posttest) was given to assess any training effects. Subsequently, the five readings prior to trigger switch closure were analyzed to determine steadiness. The resulting dependent variable was the sum of the standard deviation for "x" readings and the standard deviation for the "y" readings. A significant reduction was found in this index of variability ($t(24) = 2.14$, $p < .05$) indicating a positive training effect.

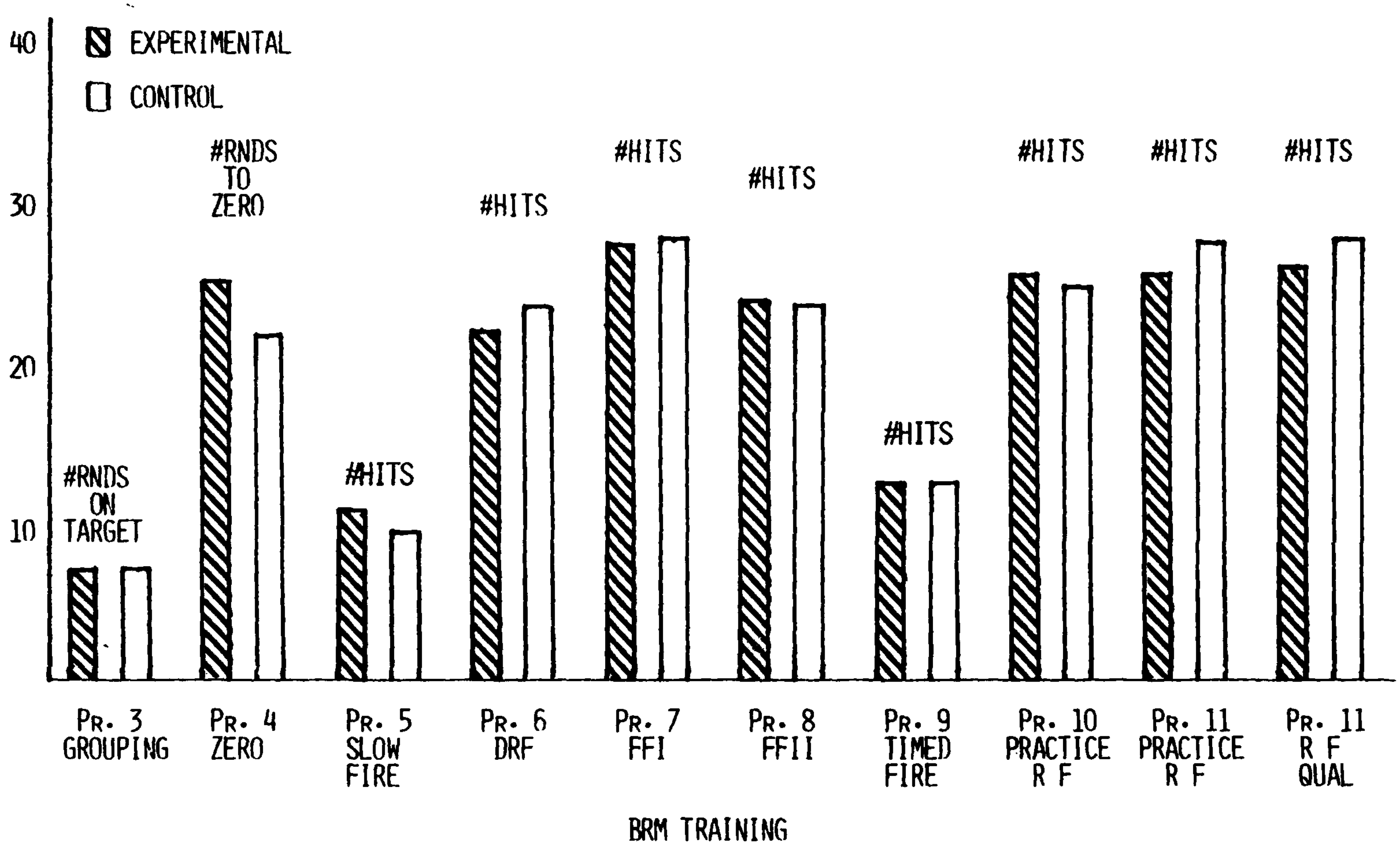

Figure 3. Mean performance during Basic Rifle Marksmanship (BRM) training of soldiers who did (experimental) and did not (control) use MACS.

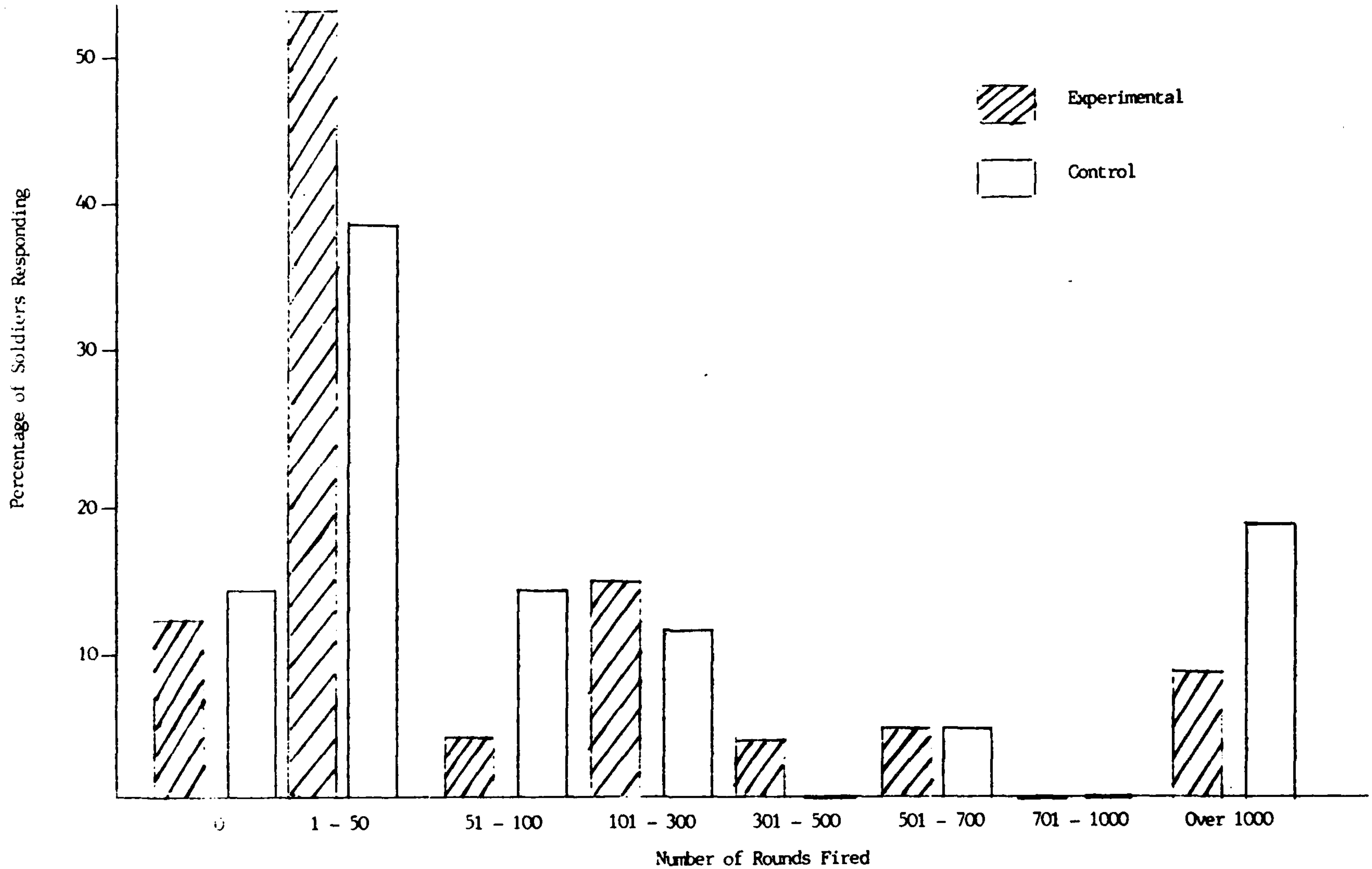

Figure 4. Prior shooting experience of soldiers participating in the MACS M16 evaluation.

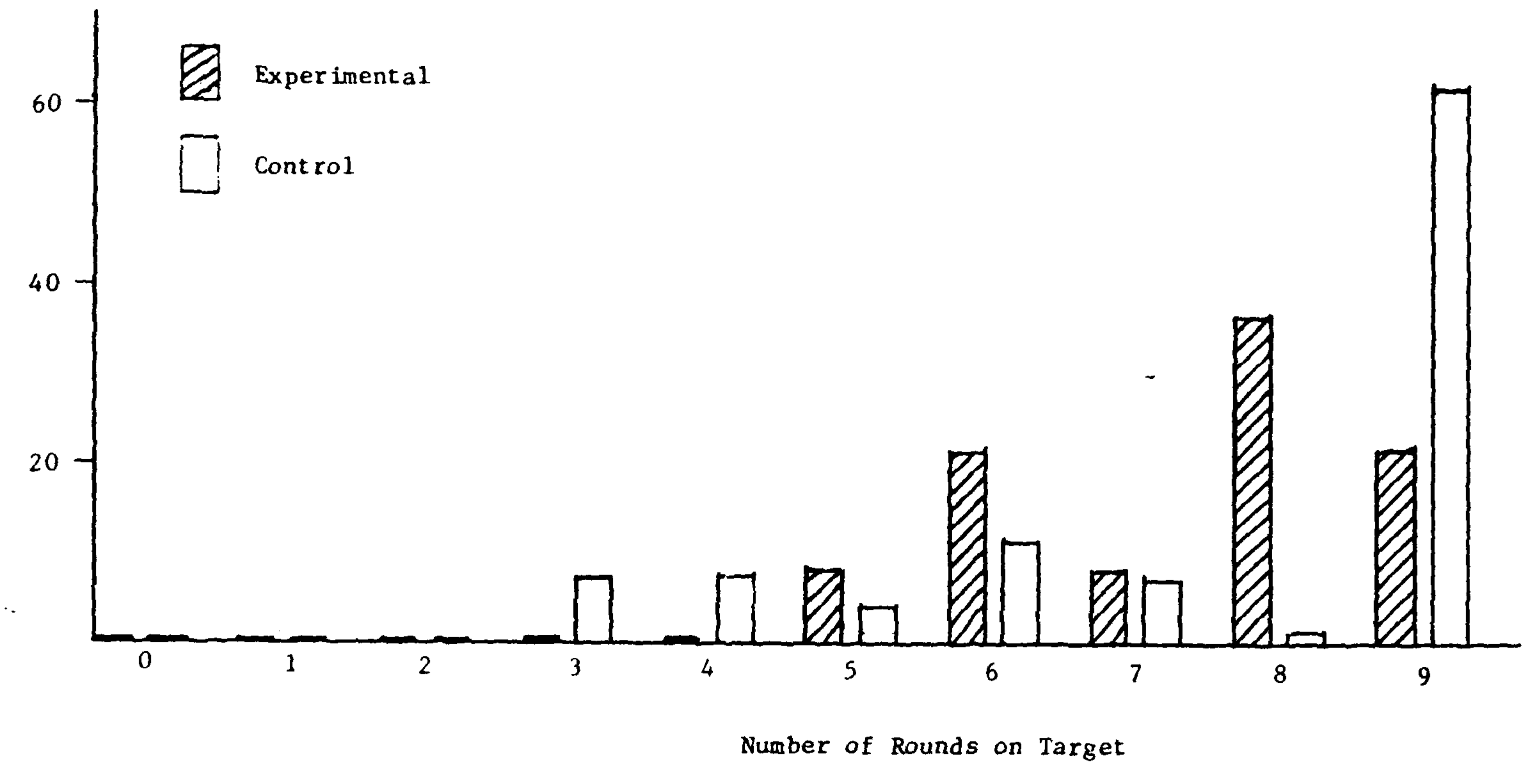

Figure 5. Frequency distribution of percentage of soldiers placing zero to nine rounds on target during BRM Period 3 training.

Other significant training effects within MACS performance were found. On the Aiming Instructional Device program (AID), there was a significant improvement in number of acceptable sight pictures (scores higher than 80) from MACS day 1 to MACS day 2 ($\underline{t}(25) = 3.49$, $\underline{p} < .01$). There was steady improvement in mean performance over the five exposures to the MACS Down Range Feedback program but the training effect was not significant ($\underline{F}(4,100) < 1.0$). There was a significant improvement in mean median performance from the first to the second exposure of the MACS Field Fire I program (mean median score, $\underline{t}(25) = 2.66$, $\underline{p} < .01$). Similarly, there was a significant increase in mean median score from the first to the second exposure to the MACS Field Fire II program ($\underline{t}(25) = 2.16$, $\underline{p} < .05$). Finally, there was improvement in mean median score for the MACS Record Fire program from the first to the second exposure, but this was not statistically significant ($\underline{t}(24) = .97$, $\underline{p} > .05$).

The correlation between scores on mean median for the two MACS Record Fire exposures and qualification scores recorded by Litton/ARI personnel was not significant ($\underline{r} = +.17$). However, inspection of the data indicated that one subject scored next to the lowest score on MACS Record Fire but the highest score on live-fire Record Fire. When that subject was removed, the correlation increased to ($\underline{r} = +.34$) but was still not statistically significant. The absence of a significant correlation between performance on MACS Record Fire and live-fire Record Fire may be due to the MACS program being too easy and, therefore, not producing a discriminating measure of marksmanship ability. Figure 6, which compares the distribution of scores on MACS RF-2 and on the live-fire Record Fire qualification test, shows that the MACS RF-2 scores are negatively skewed. Seven times more soldiers fired in the Expert class (36-40 hits) on the simulator than in live fire.

Scoring of Record Fire qualification is subject to several sources of error, such as failure by the scorer to detect a target, failure to recognize a target hit due to a target malfunction in which the target does not go down when hit, or assigning a hit when in fact the target dropped because time had expired. Although various sources of error exist, scoring of hits and misses was highly reliable. Each firing point had two scorers; one provided by the range and another from Litton/ARI. The correlation between hit/miss records from range scorers and Litton/ARI scorers was .96. Furthermore, after the soldiers had fired, the targets were collected and bullet holes were counted. There was a high correlation between the number of rounds recorded to have hit a target and the number of bullet holes ($\underline{r} = .94$, between number of rounds in each target and the number of recorded hits).

The soldiers found MACS interesting and helpful, and preferable to BRM concurrent training they had received (although that may have differed from concurrent training received by the control group). Responses to the Opinion Questionnaire were positive for all MACS training programs (Figures 7, 8, and 9). Willingness to use MACS during off-duty hours also was very high. Moreover, the soldiers considered MACS to be more interesting and more useful than concurrent training.

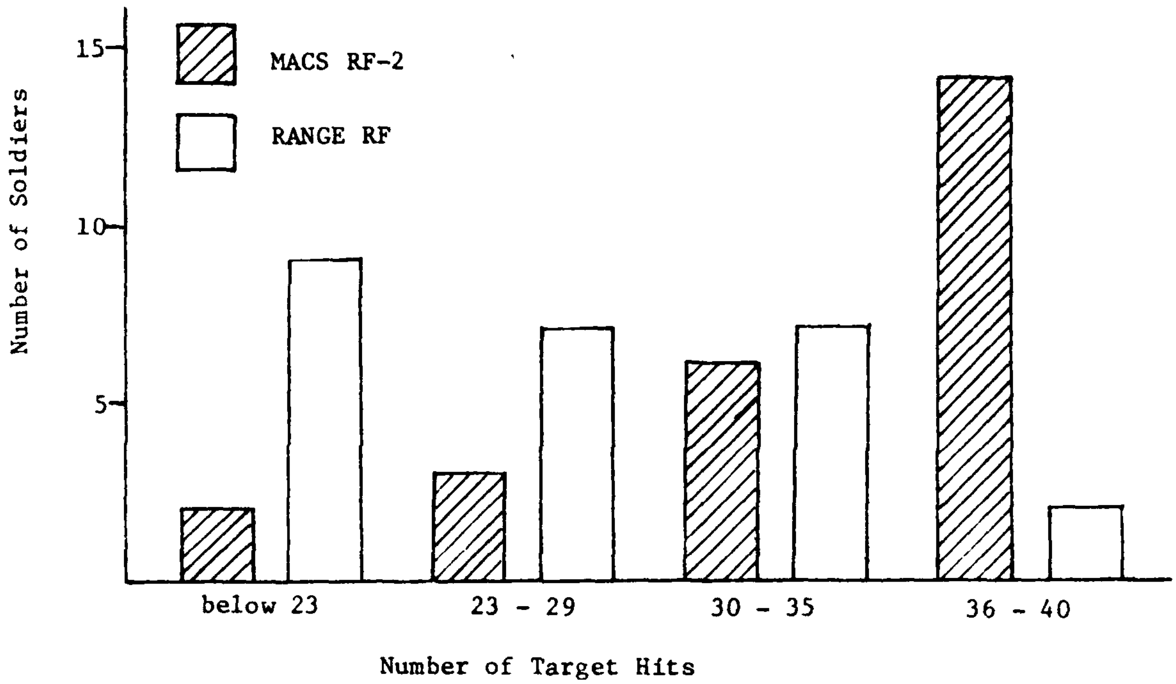

Figure 6. Frequency distribution of number of soldiers achieving 0 to 40 target hits on the second exposure to MACS Record Fire (RF-2) and on the live-fire Record Fire qualification test.

1. In your opinion, the MACS training you just received was . . .

```
|---------|---------|---------|--------*
1         2         3         4        5
very                                  very
boring                            interesting
```

2. Do you feel the MACS training you just received would help to make you a better marksman?

```
|---------|---------|---------|--------*
1         2         3         4        5
not                                    very
helpful                               helpful
```

3. If MACS were available in your company's dayroom, how often would you practice on it during your off-duty hours?

```
|---------|---------|---------|--------*
1         2         3         4        5
never                                 very
                                      often
```

4. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|---------*---------|
1         2         3         4         5
less                                   more
interesting                        interesting
```

5. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|---------*---------|
1         2         3         4         5
less                                   more
useful                                useful
```

6. How much did you learn about marksmanship from using MACS?

```
|---------|---------|---------|--------*
1         2         3         4        5
very                                  very
little                                much
```

Figure 7. MACS M16 opinion questionnaire median responses (*): Steady Position and Aiming Program.

1. In your opinion, the MACS training you just received was . . .

```
|---------|---------|---------|--------*
1         2         3         4        5
very                                 very
boring                          interesting
```

2. Do you feel the MACS training you just received would help to make you a better marksman?

```
|---------|---------|---------|--------*
1         2         3         4        5
not                                  very
helpful                            helpful
```

3. If MACS were available in your company's dayroom, how often would you practice on it during your off-duty hours?

```
|---------|---------|---------|--------*
1         2         3         4        5
never                                very
                                     often
```

4. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|---------*--------|
1         2         3         4        5
less                                 more
interesting                     interesting
```

5. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|---------*--------|
1         2         3         4        5
less                                 more
useful                              useful
```

6. How much did you learn about marksmanship from using MACS?

```
|---------|---------|---------|--------*
1         2         3         4        5
very                                 very
little                               much
```

Figure 8. MACS M16 opinion questionnaire median responses (*): Down Range Feedback Program.

1. In your opinion, the MACS training you just received was . . .

```
|---------|---------|---------|---------*
1         2         3         4         5
very                                  very
boring                             interesting
```

2. Do you feel the MACS training you just received would help to make you a better marksman?

```
|---------|---------|---------|---------*
1         2         3         4         5
not                                    very
helpful                               helpful
```

3. If MACS were available in your company's dayroom, how often would you practice on it during your off-duty hours?

```
|---------|---------|---------|---------*
1         2         3         4         5
never                                  very
                                       often
```

4. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|---------*---------|
1         2         3         4         5
less                                  more
interesting                        interesting
```

5. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|---------*---------|
1         2         3         4         5
less                                  more
useful                               useful
```

6. How much did you learn about marksmanship from using MACS?

```
|---------|---------|---------|---------*
1         2         3         4         5
very                                   very
little                                 much
```

Figure 9. MACS M16 opinion questionnaire median responses (*): Field Fire and Record Fire Program.

EVALUATION 2: MACS M203

The MACS M203 evaluation was small in scope. The M203 receives only eight hours of instruction during OSUT compared to over a week for the M16, and there was a very narrow window of time the troops were available for MACS training immediately before M203 training. As with the MACS M16 evaluation, this study should be considered a preliminary test of the MACS M203 program rather than a definitive evaluation.

Method

Subjects. Twelve and fifteen soldiers, drawn randomly from an OSUT company, served as the experimental and control subjects, respectively. Sample size was limited by time and equipment constraints.

Apparatus. The hardware configuration for MACS M203 differed from the M16 in using a Commodore 64 microcomputer instead of an Apple. The Commodore 64 has several advantages compared to the Apple including sprite graphics capabilities, a three-voice music synthesizer for sound effects, and a cartridge port. This latter feature allows MACS to be configured without floppy disk drives, thereby reducing the cost while increasing the durability of the system. Rather than using disk drives, the software can be put onto an erasable, programmable chip (E-PROM) which plugs into the Commodore's cartridge port. However, such a configuration has not yet been developed. The light pen was mounted on the M203 quadrant sight such that adjustment of the quadrant sight resulted in identical movement in the alignment of the light pen.

A detailed description of the MACS M203 program is provided in Appendix D. Briefly, the program presents six targets, one at a time, in random order and the user fires three rounds per target. Targets include point and area targets at ranges of 100 to 350 m. Range estimation requirements are built into the program as is nominal (hit/miss) as well as ratio (radial distance) scoring.

Procedure. Three MACS M203 systems were set up in the company's day room two days prior to the company's regularly scheduled M203 training. Before using MACS, the experimental subjects received a brief tutorial, conducted by Litton/ARI personnl, on how to hold and sight the M203. Each subject tried several warm-up shots on MACS, and then went through the MACS M203 program for approximately 15 min. Both the experimental and control subjects were given a shooting experience questionnaire to determine the extent of marksmanship experience with a pistol, rifle, or shotgun prior to entering the Army. Also, the soldiers' M16 Record Fire scores were used as an indication of baseline marksmanship ability.

Soldiers in OSUT receive eight hours of training on the M203 during which they fire three TP (training practice) rounds from a kneeling supported position at a zero panel (2 m x 2 m sheet metal) located 200 m down range, and two rounds (one TP and one HE, high explosive) from a foxhole position at an armored personnel carrier (APC, approximately 2.5 m wide x 2 m high) at a distance of 250 m. Using binoculars equipped with reticles marked in 10 mil increments, Litton/ARI personnel recorded the location of impact (either on or near the target) of each round fired by the experimental and control subjects. By placing the crosshairs of the reticle on the center of mass of the target, the x (horizontal) and y (vertical) coordinates of round impact could be recorded in mils. The recordings in mils were then converted to meters. Distance each round landed in reference to the target's center of mass was analyzed in terms of the x coordinate (horizontal distance) and y coordinate (vertical distance). Also, hit and miss data were recorded.

The performance of the experimental and the control subjects was compared using a three-factor analysis of variance (ANOVA) with repeated measures on two factors. Factors were Group (experimental and control), Range (200 m and 250 m targets), and Trials (the first two of the three rounds fired at the 200 m target, and the two rounds fired at the 250 m target). The dependent variables were the horizontal and vertical distance the round landed from the target's center of mass. Following a significant main or interaction effect, post hoc pairwise comparisons among means were performed using a Scheffe' test. Comparisons were made only between means for the experimental and control groups since these were of primary interest.

Results and Discussion

Observations of the live-fire M203 exercise revealed that accuracy of target engagement was primarily a function of target range and practice. Analyses were performed on horizontal and vertical distance the rounds landed from the target's center of mass. The results indicated that both the experimental and control groups hit closer to the center of mass of the target on the 200 m target compared to the 250 m target (as would be expected because of constant angular error), and the second round fired was aimed more accurately than the first round. It should be noted that target range was confounded by firing position. The 200 m target was engaged from an unsupported kneeling position, whereas the 250 m target was fired at from a foxhole supported position. The frequency of target hits also was analyzed although this is a less informative measure than location of round impact. In the opinion of three of the four Litton/ARI observers, the reliability of detecting whether or not a round hit the target was greater than estimating the distance the round landed from the target's center of mass. None of the observers had prior practice with quantifying location of round impact, and interobserver reliability measures were not collected.

The ANOVA on horizontal distance indicated statistically significant Range (200 m vs. 250 m target, $F(1,25) = 4.98$, $p < .05$) and Trials (first vs. second round fired, $F(1,25) = 9.80$, $p < .01$) main effects, and a significant Group x Range x Trials interaction effect ($F(1,25) = 5.14$, $p < .05$). The Group main effect did not reach statistical significance ($F(1,25) = 0.77$). Inspection of the data (Figure 10), and post hoc comparisons revealed that the difference between the experimental and control groups on the 250 m target that was not present for the 200 m target produced the interaction effect. The first round the controls fired at the 250 m target generally fell wide of the mark. The Scheffe' test indicated that the mean horizontal error for the first round fired at the 250 m target was statistically greater for the control group than the experimental group ($p < .05$).

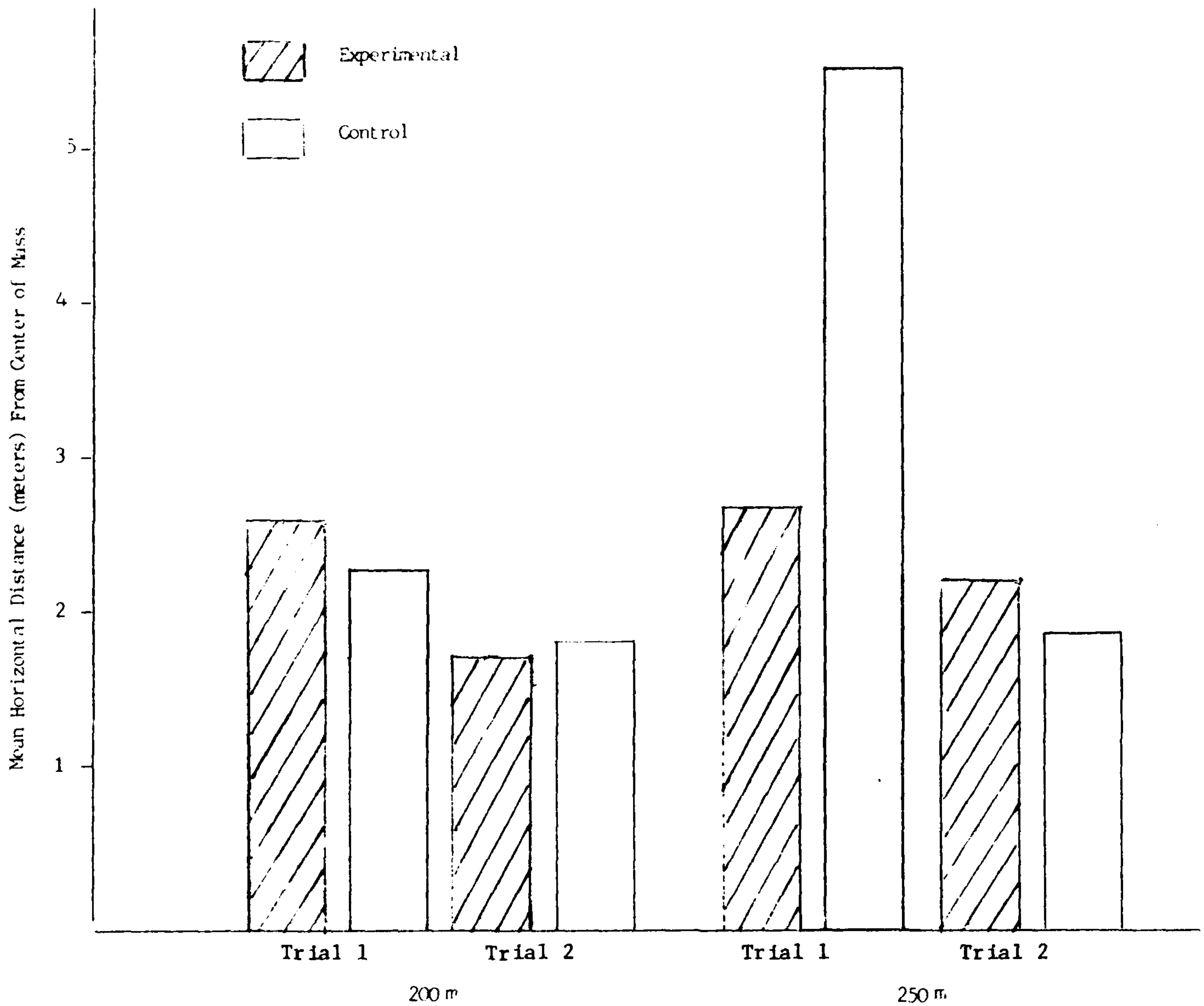

Figure 10. Mean horizontal distance M203 round landed from the target's center of mass.

Figure 11 illustrates the average vertical location of round impact. It should be kept in mind that this vertical estimate of round impact is a gross measure, confounded by being a perceptual composite of two spatial dimensions, depth and height, and should be considered a less precise measure than the horizontal estimate of round impact location. An ANOVA on vertical distance resulted in statistically significant Group ($F(1,25) = 8.16$, $p < .01$) and Range ($F(1,25) = 7.69$, $p < .05$) main effects, and a significant Group x Range interaction effect ($F(1,25) = 11.79$, $p < .01$). Post hoc analysis indicated that the experimental group hit closer to the target's center on the 250 m target for both the first ($p < .001$) and second ($p < .001$) rounds fired. On the 200 m target, both groups performed similarly on the first round fired, but the control group performed better than the experimental group on the second round ($p < .05$).

The results of the analyses on frequency of target hits were similar to those on location of round impact. Soliders who had received MACS training tended to hit the 250 m target more frequently than the controls, where as the reverse was observed for the 200 m target. Table 1 summarizes the proportion of total rounds fired by the experimental and control subjects at the 200 and 250 m targets. Also presented are the probabilities that the two groups differed in the frequency of hits, as determined by the Fisher exact probability test (Siegel, 1956). For the closer range target, the control group did better than the experimental group. However, only the comparison for the third round was statistically significant. The control group also showed improvement across trials with more soldiers being able to hit the target with each successive attempt. In contrast, the experimental group showed no such improvement. The experimental group did achieve more hits on the farther range target than the control group. However, none of the comparisons were statistically significant.

Table 1

Probability that the Experimental and Control Groups Differed in Frequency of Target Hits Using the M203

Target	Round	Proportion of Hits: Experimental	Proportion of Hits: Control	Probability[1]
200 m	1	8.3%	33.3%	.14
	2	16.7%	40.0%	.19
	3	8.3%	46.7%	.04
250 m	1	16.7%	0.0%	.19
	2	16.7%	6.7%	.41

[1] Fisher exact probability test (Siegel, 1956).

There were no significant correlations between performance on MACS and on the live-fire range. The overall correlation between median radial error on MACS and mean error (sum of x error and y error) in live-fire was $r = +.12$.

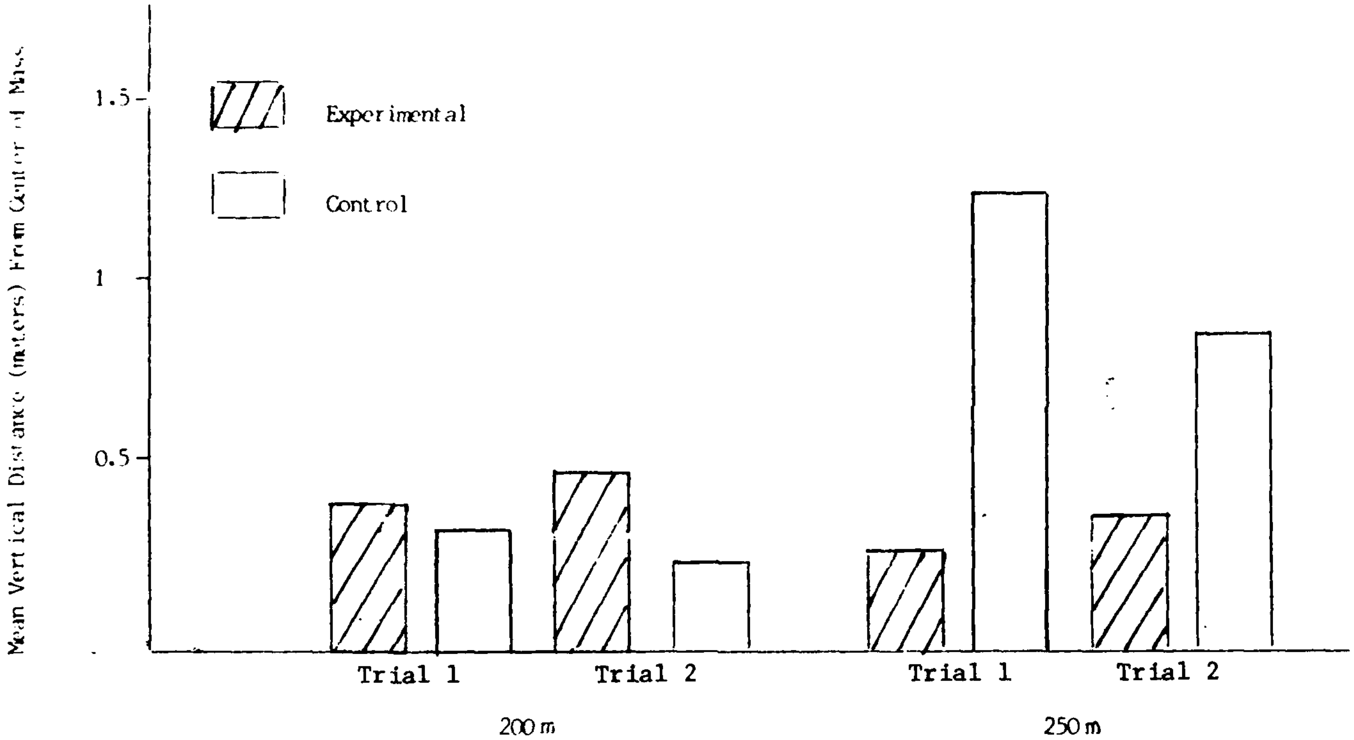

Figure 11. Mean vertical distance M203 round landed from the target's center of mass.

Since the experimental subjects fired at a 200 m target on both MACS and on the range, each of the three rounds fired at this target was compared in terms of radial distance and hit/miss. As can be seen in Table 2, the distance a round landed from the center of mass on the 200 m MACS target was not related to point of impact during the live-fire exercise for any of the three trials. Similarly, whether or not a soldier was able to hit the 200 m MACS target was of little relation to hitting the live-fire target.

Comparisons between performance on MACS and on the live-fire range should be interpreted cautiously since the instructional procedure used on the range seldom permitted the soldier to apply the principles learned from using MACS. MACS requires the soldier to estimate the target's range, set the M203 quadrant sight, fire, observe location of round impact, and then adjust point of aim and/or readjust the range on the quadrant sight to obtain a more accurate target engagement on the next round fired. In contrast, during the live-fire exercise, the soldiers are told the target's range (i.e., there is no opportunity to practice range estimation). Immediately after firing, but prior to round impact, they are told to reload and therefore cannot always observe the location of round impact. Instead, the instructor tells the soldier how to adjust point of aim and/or how to readjust the quadrant sight for firing the next round. Occasionally, soldiers had the opportunity to observe location of round impact, but they rarely were given the time to do their own problem-solving, which is a primary purpose of MACS.

Figure 12 illustrates that the experimental and control soldiers had a similar amount of experience with firearms prior to entering the service. Soldiers were asked to estimate the number of times they had fired a pistol, rifle, and shotgun before joining the Army. The proportion of soldiers whose estimates fell within a class interval is presented in Figure 12. As another measure of baseline ability, mean M16 Record Fire scores were similar for the experimental ($\bar{x}$ = 28.7) and control ($\bar{x}$ = 26.7) groups $\underline{t}(24) = 0.88$.

The reactions to MACS M203 were quite favorable. Responses to the opinion questionnaire, presented in Figure 13, indicated that MACS M203 was very interesting and helpful, especially compared to concurrent training. Moreover, soldiers reported that they would use MACS "very often" during their off-duty hours if it were available in their dayroom.

Table 2

Correlations Between MACS M203
and Live Fire Performance on the 200 Meter Target

Observation	Dependent Variables	r
Trial 1	Live-Fire Radial Error and Score on MACS	.01
Trial 2	Live-Fire Radial Error and Score on MACS	.09
Trial 3	Live-Fire Radial Error and Score on MACS	.08
Trial 1	Hit/Miss in Field Fire and Hit/Miss on MACS	.36
Trial 2	Hit/Miss in Field Fire and Hit/Miss on MACS	.00
Trial 3	Hit/Miss in Field Fire and Hit/Miss on MACS	.25

Note: All correlations are statistically nonsignificant, df = 10.

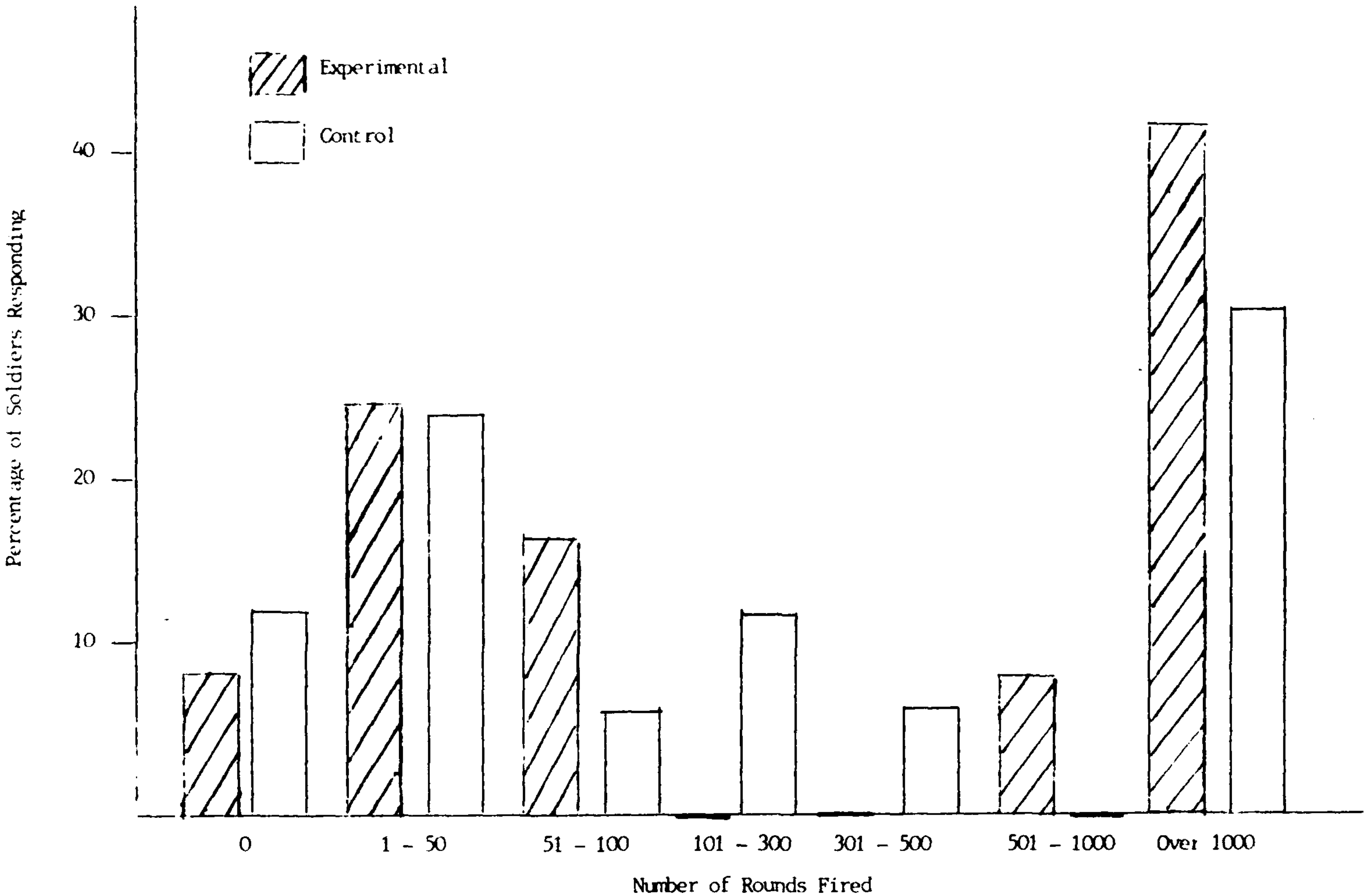

Figure 12. Prior shooting experience of soldiers participating in the MACS M203 evaluation.

1. In your opinion, the MACS M72A2 training you just received was . . .

|---------|---------|---------|--------*

1 2 3 4 5

very boring — very interesting

2. Do you feel the MACS training you just received would help you to fire the M203 more accurately?

|---------|---------|---------|--------*

1 2 3 4 5

not helpful — very helpful

3. If MACS were available in your company's dayroom, how often would you practice on it during your off-duty hours?

|---------|---------|---------|--------*

1 2 3 4 5

never — very often

4. Compared to today's concurrent training, MACS training was . . .

|---------|---------|---------|----*----|

1 2 3 4 5

less interesting — more interesting

5. Compared to today's concurrent training, MACS training was . . .

|---------|---------|---------|----*----|

1 2 3 4 5

less useful — more useful

6. How much did you learn about the M203 from using MACS?

|---------|---------|---------*---------|

1 2 3 4 5

very little — very much

Figure 13. MACS M203 opinion questionnaire median responses (*).

EVALUATION 3: MACS M72A2

The final weapon system in this series of evaluations was the MACS M72A2 Light Antitank Weapon. As with the M16 and M203 studies, the M72A2 study should be considered a preliminary investigation of the system.

Method

Subjects. Thirteen and nineteen soldiers, selected randomly from an OSUT company, served as the experimental and control participants in the MACS M72A2 study, respectively. (A different company was used for each of the MACS studies). These soldiers had completed M16 and M203 training, but had not yet received any training on the M72A2.

Apparatus. The hardware was the same Apple configuration used for the MACS M16. A light pen was mounted inside the barrel of an expended M72A2 near the end with the front sight. The instructional design of the software was the same as for the MACS M16 Steady Position and Aiming Training Program. Targets included a Russian BRDM vehicle at four ranges: 100, 175, 250, and 325 m. A detailed description of the software is provided in Appendix E.

Procedure. Three MACS M72A2 units were set up in a classroom in the company's area the day before M72A2 live fire training. All subjects were given a "prior shooting experience" questionnaire and a 10 min. tutorial conducted by Litton/ARI personnel on the M72A2. The experimental subjects then received training on the MACS M72A2 program for approximately 15 min.

Soldiers in OSUT receive eight hours of "hands on" training with the M72A2, part of which is devoted to a live-fire exercise. During the live-fire training, Litton/ARI personnel were on the range with the experimental and control troops to record their performance. Each soldier fired three 35mm subcaliber rockets, one round at each target range of 100, 175, and 275 m. Targets were armored personnel carriers. The procedure for recording the location of round impact was the same as for the M203 study. Following the live-fire exercise, the experimental subjects completed an opinion questionnaire similar to the one used in the M16 and M203 studies. Additionally, the soldiers' M16 Record Fire scores were used as an indication of baseline marksmanship ability.

Dependent variables were the same as those in the M203 study: horizontal and vertical distance the rocket landed from the target's center of mass. Unfortunately, several of the rounds that missed the target also were outside the field of view of the binoculars, so data for these "lost" rounds were unavailable for analysis. Some of the lost rounds were known to be duds in which point of impact was unknown because they did not explode. Due to the unequal number of data points, separate comparisons between experimental and control subjects were performed, using a t-test, for each range.

Results and Discussion

Table 3 shows that the experimental group hit the target more frequently than the control group, especially on the longest range target; however, these differences were not statistically significant. The experimental group also tended to hit closer to the target's center of mass compared to the control group. Figure 14 illustrates the average horizontal and vertical distance the M72A2 rockets landed from the target's center at ranges of 100, 175, and 275 m. Again, there were no statistically significant differences between groups, nor did the groups do better on closer than farther targets. It should be noted that performance at the different ranges is confounded by trials. That is, the 100 m target represents the first round fired, whereas the 275 m target is also the soldiers' third live-fire trial. All rounds were fired from the same position.

Table 3

Probability that the Experimental and Control Groups Differed in Frequency of Target Hits Using the M72A2

Target	Proportion of Hits: Experimental	Proportion of Hits: Control	Probability
100 m	69.2%	57.9%	.39[1]
175 m	69.2%	68.4%	.64[1]
275 m	61.5%	26.3%	<.20[2]

[1] Fisher exact probability test (Siegel, 1956).

[2] χ^2 test for smallest expected frequencies > 4 and $20 < n < 40$ (formula 6.4, Siegel, 1956).

These distance measures may not accurately reflect the group differences in that only data for rounds that exploded within the binoculars' field of view were available. Table 4 summarizes the proportion of total rounds fired at each target range that were lost (outside the binoculars' field of view or duds) for the experimental and control groups. The χ^2 test showed the two groups to be similar in the frequency of lost rounds.

Table 4

Probability that the Experimental and Control Groups Differed in Frequency of Lost Rounds Using the M72A2

Target	Proportion of Lost Rounds: Experimental	Proportion of Lost Rounds: Control	Probability
100 m	7.7%	26.3%	.20[1]
175 m	7.7%	10.5%	.64[1]
275 m	38.5%	26.3%	<.80[2]

[1] Fisher exact probability test (Siegel, 1956).

[2] χ^2 test for smallest expected frequencies > 4 and $20 < n < 40$ (formula 6.4, Siegel, 1956).

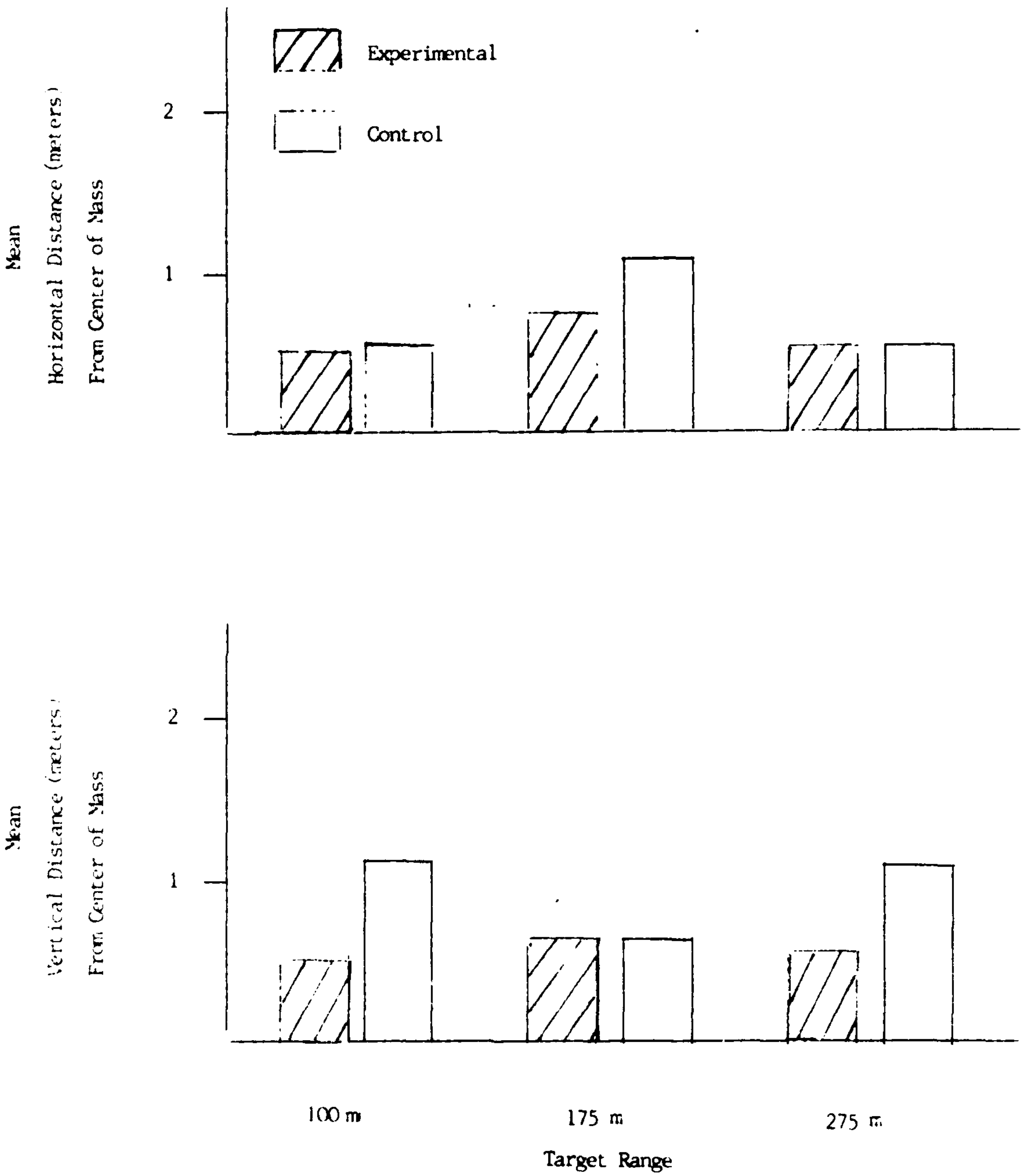

Figure 14. Mean distance M72A2 rounds landed from the target's center of mass.

There was no significant correlation between the experimental group's performance on MACS and their performance on the live-fire range. The overall correlation between MACS performance (% of scores outside the first ring) and mean error (sum of x error and y error) in live fire was $r = +.24$. Table 5 illustrates that for the two target ranges common to both the MACS M72A2 scenario and the live-fire exercise (100 and 175 m), location of round impact on MACS was not predictive of location of round impact during live fire as measured by horizontal, vertical, and radial distance from the target's center of mass. Furthermore, the total number of target hits achieved using MACS was not significantly correlated to the number of target hits during live fire.

Figure 15 shows that overall the groups did not differ remarkably in experience with firearms prior to entering the service, although there were a few more soldiers firing over 300 rounds in the experimental than control group. As another measure of baseline ability, mean Record Fire scores were similar for the experimental ($\bar{x} = 28.3$) and control ($\bar{x} = 30.5$) groups ($t(29) = 0.98$).

Table 5

Correlations Between MACS and M72A2 Live-Fire Performance

Dependent Variable	Target	r[1]
Horizontal distance	100 m	.20
	175 m	-.01
Vertical distance	100 m	.57
	175 m	.44
Radial distance	100 m	.07
	175 m	.08
Total number of hits	all	.41

[1] All correlations are statistically nonsignificant, df = 10.

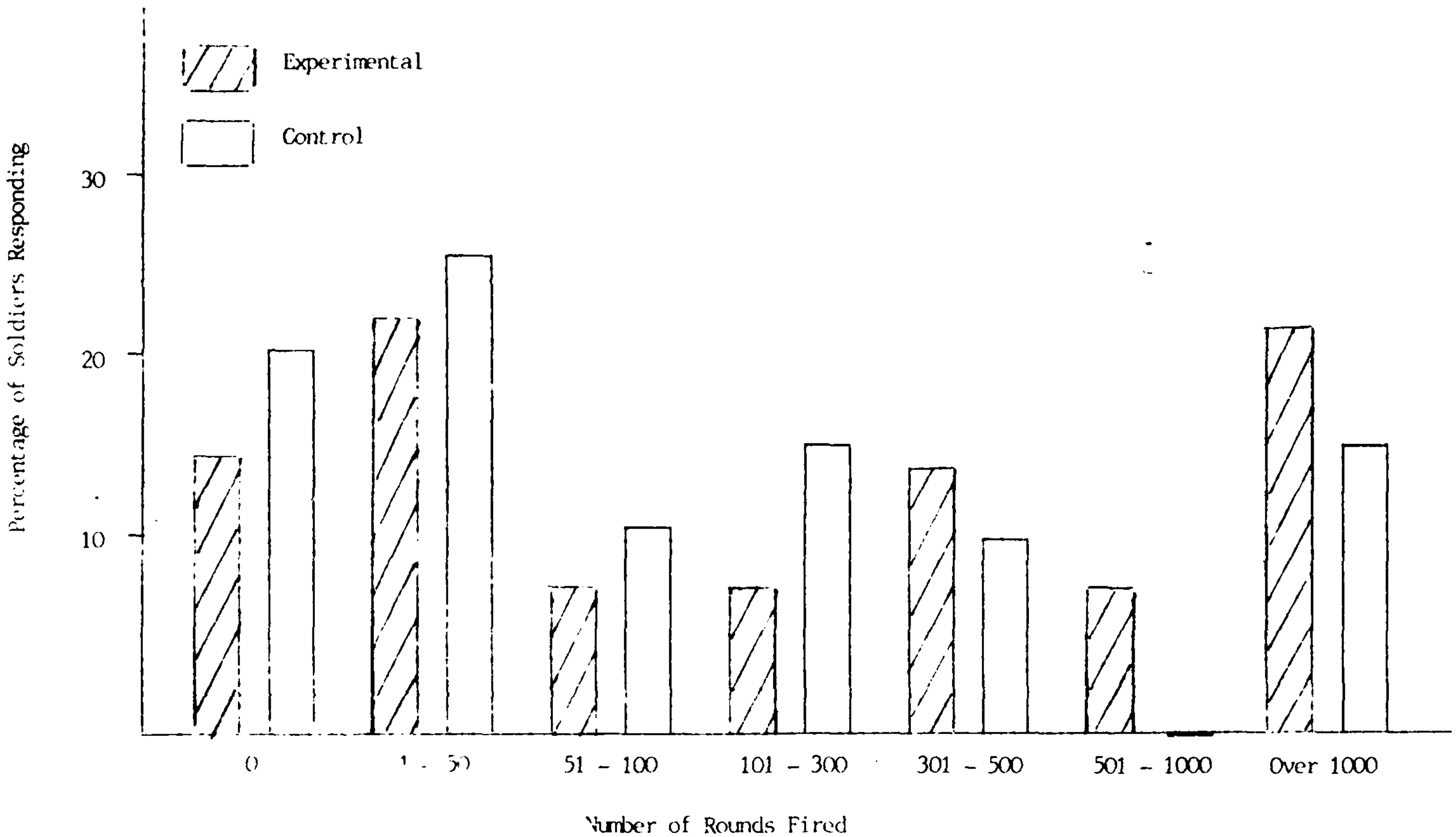

Figure 15. Prior shooting experience of soldiers participating in the MACS M72A2 evaluation.

Soldiers were divided on their opinions of the MACS M72A2. Most soldiers thought that the MACS M72A2 was interesting (Figure 16, question #1), helpful (question #2), and that they learned (question #6) from using it. Most soldiers were noncommital about whether they would use MACS during their off-duty hours (question #3). This could be attributed to equipment problems giving the impression that the system is finicky to use. The M72A2 is not designed as a reuseable weapon. In fact, it is issued as ammunition and intended to be thrown away after firing. Budget considerations require the ranges to retain the expended M72A2 tubes and reuse them many times for training. Similarly, MACS uses a standard M72A2 tube which suffers considerable wear from recocking and makes the weapon difficult to prepare for firing. A switch was added at the rear of the M72A2 which is tripped when the weapon is cocked and tells the computer that the soldier has prepared the weapon for firing. During the study, hardware problems were encountered with the switch such that when the weapon was cócked, the switch mechanism was banged, causing improper functioning. Additionally, although the light pen was mounted as securely as possible inside the inner tube of the weapon, repeated cocking of the weapon would slightly displace the light pen, resulting in inaccurate readings. Despite the equipment problems, most soldiers thought MACS was better than concurrent training (questions #4 and #5).

GENERAL DISCUSSION

The purpose of this effort was to conduct limited experimental evaluations on prototypic versions of MACS configured for the M16, M203, and M72A2. These results should be interpreted as preliminary and applicable as guidelines for further development and more controlled investigations.

MACS showed potential as a cost-effective training aid. This simulator can contribute to a more favorable learning environment by providing (1) standardized instruction that ensures all trainees receive the same high quality training, (2) one-on-one instruction, and (3) a motivating supplement to traditional dry-fire exercises. This last factor was especially highlighted in the responses to the opinion questionnaires. Soldiers reported that MACS training was very interesting and helpful, and preferable to traditional concurrent training. When evaluating a training method, it is important to consider the student's attitude toward the method because motivation to master a skill is a critical factor for learning.

The data indicated that MACS training, when given prior to live-fire instruction, may give soldiers a head start in the acquisition of marksmanship skills. In the MACS M203 and MACS M72A2 studies, which limited MACS training to a brief exposure prior to live-fire training, there was a trend for the experimental groups to hit more targets, and to place live rounds closer to the center of mass of the target, especially on the farther targets. In contrast, the MACS M16 experimental group spent over 500% more time on the simulator than did the trainees in the MACS M203 or MACS M72A2 studies, and the exposure was distributed concurrently with regularly scheduled training. Since the results indicated that the effectiveness of MACS may vary as a function of exposure schedule, further investigation is recommended to determine the most appropriate stage of training to use MACS, and the amount of time needed to impart an effect.

1. In your opinion, the MACS M72A2 training you just received was . . .

```
|---------|---------|--------*---------|
1         2         3        4         5
very                                very
boring                       interesting
```

2. Do you feel the MACS training you just received would help you to fire the M72A2 more accurately?

```
|---------|---------|--------*---------|
1         2         3        4         5
not                                 very
helpful                          helpful
```

3. If MACS were available in your company's dayroom, how often would you practice on it during your off-duty hours?

```
|---------|--------*---------|---------|
1         2        3         4         5
never                               very
                                   often
```

4. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|--------*---------|
1         2         3        4         5
less                                more
interesting                  interesting
```

5. Compared to today's concurrent training, MACS training was . . .

```
|---------|---------|----*----|---------|
1         2         3         4         5
less                                 more
useful                             useful
```

6. How much did you learn about the M72A2 from using MACS?

```
|---------|---------|--------*---------|
1         2         3        4         5
very                                very
little                              much
```

Figure 16. MACS M72A2 opinion questionnaire median responses (*).

The present study encountered numerous uncontrolled factors which may have biased the results. Common to all three studies is the question of quality of weapons. Prior to any live-fire exercise, all weapons should be checked for proper functioning and zero. This was not done in the present study and especially may have been a factor during early exposure to live fire for all three weapons.

During the M16 live-fire exercises, there were not enough Litton/ARI personnel on the range to observe every firing station. Therefore it is not known whether all soldiers had the opportunity to fire all allotted rounds or whether their performance was biased by weapon, ammunition, or target malfunctions. Also, accuracy of data could not be ensured since records were obtained from the instructors, as recorded by the soldiers, rather than being collected first-hand by the experimenters. Although these and other factors may have contaminated the M16 results, when conditions were subjected to more control, a treatment effect was still not evident. During the M16 Record Fire qualification test, hit/miss data were collected first-hand by Litton/ARI personnel, yet the mean scores for the control and experimental soldiers were similar. It is recommended that future investigations begin by screening weapons for proper function and zero, or perhaps have everyone fire the same weapon. Then, prior to any training, all subjects should be tested for baseline marksmanship ability, perhaps using Location of Miss and Hit (LOMAH) equipment or Known Distance (KD) ranges so that precise information about location of hits and misses can be collected. Any subsequent live-fire data should be monitored closely to account for all rounds fired.

Further research is needed to determine the most effective use(s) for MACS. The programs in the study were designed to replicate current OSUT training. Perhaps MACS could be used more effectively for training skills that cannot be taught adequately on the range. For example, ARI has already developed MACS training for many of the BRM familiarization topics such as night firing, moving targets, hold off due to wind, or firing while wearing a protective mask. Perhaps this is the area where MACS benefits will be the greatest.

The hardware components of MACS held up well under field use, but not without some anticipated difficulties. The most sensitive component is the light pen (attached to the weapon) which reads the raster scan on the monitor and provides the microcomputer with the x and y coordinates signifying where the weapon is currently aimed. Previous research found that the reliability of the light pen is affected by the brightness of the monitor's screen (Schroeder & Cook, 1983), and it was with this variable that some problems were encountered during the MACS M203 study. Occasionally, the light pen would fail to read the screen coordinates, even though the light pen apparently had been working correctly. Readjustment of the screen's brightness corrected the problem.

Another important factor is the physical stability of the light pen. All of the MACS programs begin with a zero routine which requires the user to aim the weapon at a target on the screen and fire several shots. This routine allows the computer to calculate the offset between the trainee's point of aim and the location of the screen that the light pen is reading. If the light pen is accidentally bumped so that it is no longer in the same position relative to the weapon, the previously calculated offset will no longer apply and the light pen has to be re-zeroed. It is therefore critical that the light pen be securely mounted to the weapon. Even through normal use, the light pen may become displaced as was the case in the MACS M72A2 study, causing inaccurate reading. The M72A2 itself was difficult to use since it does not (and was never designed to) withstand repeated use. A more durable version of the M72A2 equipped with a more stable light pen mount and more rugged cocking switch would be valuable additions to future versions of the MACS M72A2.

The addition of noise and recoil may improve the training effectiveness of the MACS M16 system. However, MACS was intended to be a low-cost, part-task simulator and additional features mean additional cost. Although increased cost could be justified by training effectiveness, the use of Weaponeer, which has noise and recoil, has not been demonstrated to improve record fire qualification scores (Schendel, Heller, Finley, & Hawley, 1983). Nevertheless, the possibility exists that repeated exposure to a simulator without noise and recoil may sensitize the firer to these characteristics and perhaps promote "gun shyness."

These preliminary evaluations provided valuable guidelines for further research on MACS. Most importantly, stricter experimental control procedures need to be applied to the collection of live-fire data in order to demonstrate training effectiveness. Also, research is needed to identify the most appropriate training goals for MACS. It would be helpful to consider which stage(s) of instruction (i.e., skill acquisition, diagnosis of problems, remediation of problems, and sustainment of skill) would most benefit from MACS. Additionally, MACS programs in the present study were oriented toward simulating current live-fire training. However, MACS may have more training value when it presents scenarios that teach skills that are difficult to practice on the range, such as night firing or compensating for wind effects.

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APPENDIX A

DESCRIPTION OF MACS M16 PROGRAMS

For the M16, six computer training programs were developed, each compatible with training objectives in the Basic Rifle Marksmanship (BRM) program of instruction. These programs are:

1. MACS Steady Position and Aiming - Pretest and Posttest (BRM Period 2). This program records the soldier's ability to engage the target and to hold a steady position before the trigger squeeze. This program was given to all subjects before (pretest) and after (posttest) training on Program 2 below. Performance is recorded using both a supported and unsupported firing position.

2. MACS Steady Position and Aiming Training (BRM Period 2). This program features immediate audio and video feedback, as well as delayed video playback. A flow chart of the instructional design for this program is provided in Figure 17. Silhouette targets scaled to one of four distances (75, 150, 250, or 300 meters) appear randomly on the screen, and the soldier is instructed to aim and fire at the target. In Stage I of the two-stage exercise, the soldier receives immediate audio feedback about the accuracy of point-of-aim. Additionally, an instructor or partner can monitor the simultaneous video feedback and relate points of correction to the shooter. After the soldier fires, a dot appears on the screen indicating the location of the shot. In Stage II, the soldier no longer receives audio feedback pertaining to point-of-aim. After each shot, the computer replays the soldier's point-of-aim during the 2-5 second period prior to the shot. Trajectory is built into all MACS software for all target ranges.

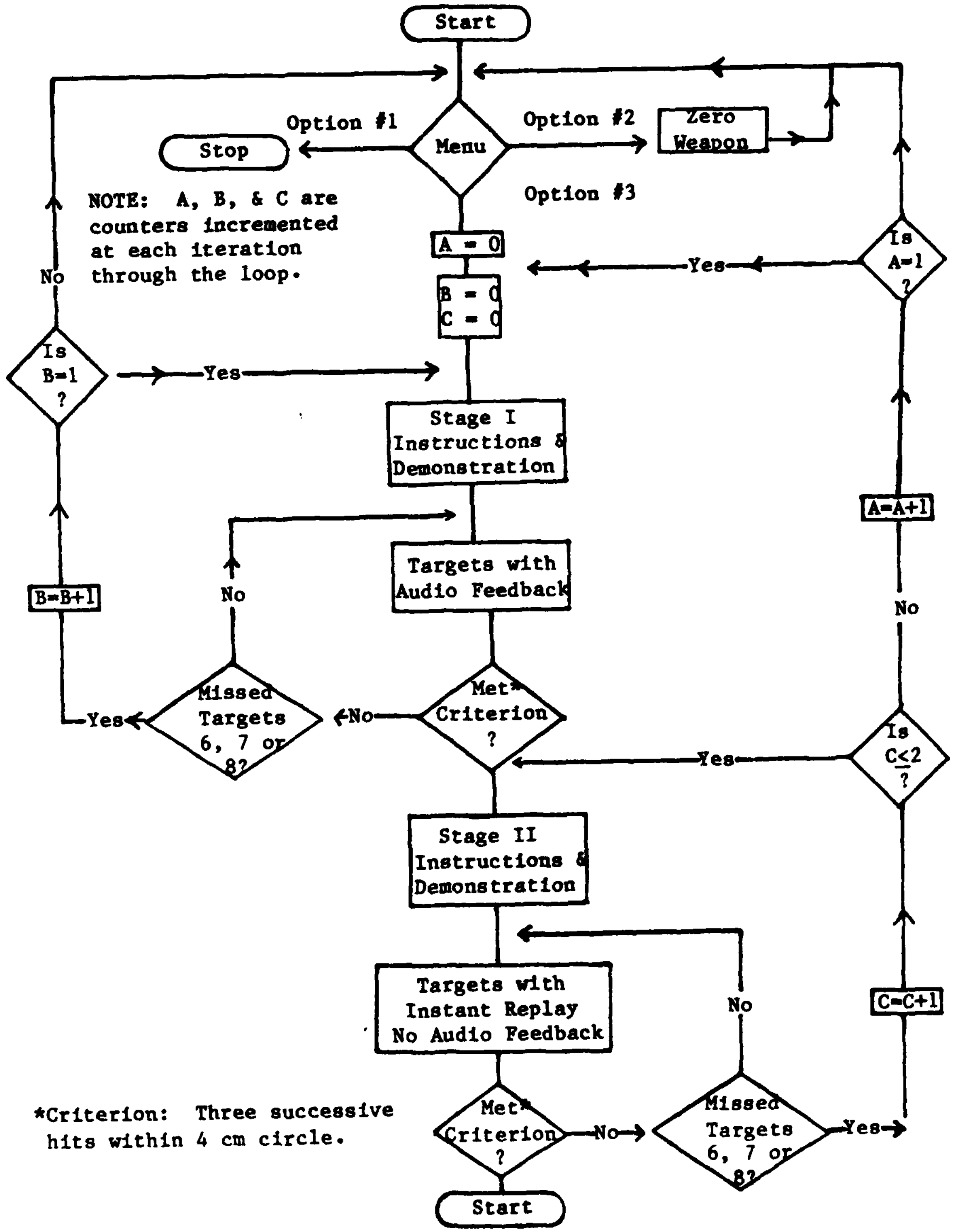

Figure 17. Instructional Design for MACS M16 Steady Position and Aiming Training Program.

3. MACS Down Range Feedback (BRM Periods 5 and 6). In this program, the soldiers are presented with single, untimed, stationary, scaled silhouette targets. Simulated target ranges include 75, 150, and 300 meters. Each target distance appears in the lower right-hand corner of the screen. The soldiers fire a three-round shot group at each target and receive immediate audio and visual feedback for each round. The x and y cartesian coordinate of each shot is stored. Soldiers receive scores dependent on radial distance from center mass for each round and cumulative scores. Hard copy records of soldier performance are optional. As with all of the MACS M16 programs, the soldier must perform the scenario from a supported, as well as unsupported position.

4. MACS Field Fire I (BRM Period 7). This program presents single, timed targets that fall when hit. The times vary from 5 sec for the closer targets to 10 sec for the farther ones. The ranges presented are the same as those in MACS Down Range Feedback. The soldier has one round per target, and records are kept of each round fired. The records contain radial distance from center mass, hit/miss, target range, and presentation number (a presentation is any time one or more targets appear on the screen). At the end of the scenario, the computer displays the number of hits, number of misses, and number of no fires. These records may be printed if the instructor desires.

5. MACS Field Fire II (BRM Period 8). This program includes all of the features in MACS Field Fire I, with the addition of multiple as well as single target presentations. Record keeping is similar to Field Fire I with the addition of penalties assessed when the soldier kills the farther target before the closer one.

6. <u>MACS Record Fire (BRM Periods 10 and 11)</u>. This program simulates record fire exercises in BRM. The computer generates scaled silhouette targets which are presented for a limited amount of time and includes single and multiple presentations. Simulated ranges include 75, 100, 150, 200, 250, and 300 meters. Showing the location of bullet strike is optional, depending upon whether the instructor or soldier wishes to simulate record fire by not being able to see bullet strike, or whether more feedback is desired by showing where the bullet hit the target. Hard copy records of student performance may be maintained. The record keeping is the same as that in Field Fire II.

APPENDIX B

TARGET SCALE VERIFICATION

The scaled size of each target range was computed using the following formula:

$$\frac{\text{actual target size}}{\text{actual target distance}} = \frac{\text{scaled target size}}{\text{scaled target distance}}$$

where

actual target size = 32.7 cm high x 66.0 cm wide for "F" silhouette; 86.4 cm high x 49.2 cm wide for "E" silhouette

actual target distance = 75 and 100 m for "F" silhouette 150 to 300 m for "E" silhouette

scaled target size = unknown

scaled target distance = 3.048 m (or 10 feet) the distance from the firer's eye to the TV screen

The scaled size in centimeters was converted to pixels. The number of pixels per centimeter varies depending upon the monitor.

After the scale of each target was programmed, the scaled size was verified by measuring the width of each target as it appeared on the screen using a caliper. Two people took two measurements of each target and the four scores were averaged. As can be seen in Table 9 the screen measurements compared favorably with the computed sizes.

Target scale also was verified using a photographic procedure. Photographs (35mm) were taken of each target as it appeared on the monitor screen. Photographs also were taken out on a firing range of "E" silhouette targets placed at actual distances. Again, the sizes of the MACS scaled targets compared favorably with actual range targets (Table 6).

Table 6

Target Scale Verification

Target	Computed Width	Screen Width	Photo Width MACS	Photo Width Range
50 m	(6.00)			
75 m	2.68 cm	Baseline: 2.49 cm Shoulders: 2.08 cm		
100 m	(2.00) 2.01	Baseline: 1.79 cm Shoulders: 1.49 cm		
150 m	(1.00) 1.01 cm	0.99 cm	0.14	0.14
200 m	(.75) 0.75 cm	0.80 cm	0.10	0.09
250 m	(.60) 0.60 cm	0.53 cm	0.09	0.08
300 m	(.50) 0.50 cm	0.50 cm	0.07	0.07

APPENDIX C

PREVIOUS SHOOTING EXPERIENCE QUESTIONNAIRE

NAME ______________________________ DATE ____________________

ROSTER # ___________________________

How many times have you fired a pistol? __________

How many times have you fired a rifle? __________

How many times have you fired a shotgun? __________

How many times have you been hunting? __________

How many times have you been target shooting? __________

Do you consider yourself a good shot? Yes _____ No _____

Don't Know ________

APPENDIX D

DESCRIPTION OF MACS M203 PROGRAM

1. Zeroing panel is displayed. The program begins with the instructor firing five rounds at the panel to allow the computer to zero the light pen to the weapon. During the zero phase, the computer is constantly taking light pen readings. After each shot, the computer takes the last five light pen readings. Both the x values and y values are sorted and the median value of each is assigned to the x and y coordinates of that shot. After all five shots have been fired, the computer sorts the x and y coordinates of the five shots. The median values of each are then defined as the coordinates for the center of the shot group. The offset from the center coordinates to the center of the zeroing panel are then calculated. This offset is added to all shots fired during the remainder of the simulation. The five zero shots are then displayed to show the shot group.

2. Scene is displayed. 100, 200, and 300-meter markers are displayed together with a message telling the soldier to take note of the ranges relevant to the scene displayed. This is the only time these range markers are shown.

3. Range selection menu. Ranges from 25 to 400 meters in 25-meter increments are displayed. These ranges match those on the quadrant sight. One at a time, each range is highlighted. When the desired range is highlighted, the soldier squeezes the trigger to select it.

4. Keep or reselect range. After range selection, the computer allows the soldier to keep this range or select a new range:

   a. Reselect - will display the range selection menu once again.

   b. Keep - soldier is told to set the quadrant sight at the selected range and engage the target.

5. <u>Targets</u>. Six targets appear in random order and within a random range on the horizontal axis:

window	100 m
troops	300 m
bunker	150 m
weapon position	200 m
bunker	125 m
troops	350 m

6. <u>Engaging the target</u>. The appropriate time delay from firing to impact is incorporated along with an explosion and appropriate time delay from round impact to sound of explosion. After each round, the computer provides feedback about the outcome of that round. For point targets (windows and bunkers), the computer displays hit, direct hit, or miss. For area targets (weapon positions and troops in the open), the computer displays kill, direct kill, or no kill. The computer also provides the following error messages:

Incorrect range selected
Incorrect point of aim
No error

The soldier fires three rounds per target and has the option to select a new range after each firing if the previous range selected is incorrect.

7. <u>Scoring and Record Keeping</u>.

a. Scoring is determined by the radial distance from round impact to center mass of the target with a maximum score of 100 points per round. At the end of the scenario, the computer displays the total number of hits and misses, cumulative score, and percentage of maximum possible score. It also displays hits and score broken down for each target range.

b. Scores are saved on disk and/or printed as selected by the instructor/user. Scores printed will contain soldier identification number, range selected, radial distance and score for each round fired.

APPENDIX E

DESCRIPTION OF MACS M72A2 PROGRAM

1. Targets. The target chosen for the M72A2 training is the Russian BRDM vehicle. There are four ranges at which the vehicles appear: 100 meters, 175 meters, 250 meters, and 325 meters. The order in which they appear is random. Included is the appropriate missile time delay from firing to impact. There is a simulated explosion and the point of impact is shown.

2. Initiation. The program begins with the student firing 5 rounds at the BRDM at 175 meters to allow the computer to zero the light pen to the weapon. The M72A2 does not need to be recocked between shots and the student should be told to maintain the most steady position possible during the zeroing process. If the shot group is tight enough, the shot group is shown, otherwise the student will have to rezero. An appropriate message will be displayed whenever the weapon needs to be recocked.

3. Stage I. After a successful zero, the student proceeds to the training portion of the program. The instructional design is the same as for the MACS M16 Steady Position and Aiming Training Program. Instructions are shown on the use of the program and then a demonstration for Stage I is given. Stage I is completed when the firer hits 3 consecutive BRDM vehicles near center of mass.

4. Stage II. Upon completing Stage I, the student advances to Stage II. Instructions and a demonstration are given for Stage II before beginning. This stage is completed when the student consecutively hits 3 BRDM vehicles near center of mass or at a critical area (drive train or fuel tank).

5. Record Keeping. Records may be kept by inserting a diskette in Drive #2 and selecting "Y" at the beginning of the program when asked "Do you wish to keep records? (Y/N)." A separate program is included that allows a hardcopy of the records to be obtained. The printout includes the soldier's identification number, the range of the target, and the point of impact. The point of impact is given by a ring number and angle. A set of bull's eye-type rings are superimposed over the target with the innermost ring at the target's center of mass. This inner ring is designated Ring 0 and the remainder of the rings are numbered consecutively. The angle is determined by imagining a clock, where 12:00 is a 90^{o} angle and 9:00 is a 180^{o} angle.